Alternative Fuels Strategy and Results

September 2009

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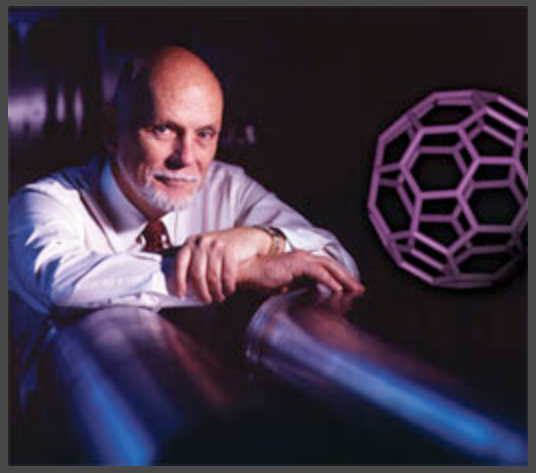
"Energy is the single most important challenge facing humanity today" Richard Smalley 2004

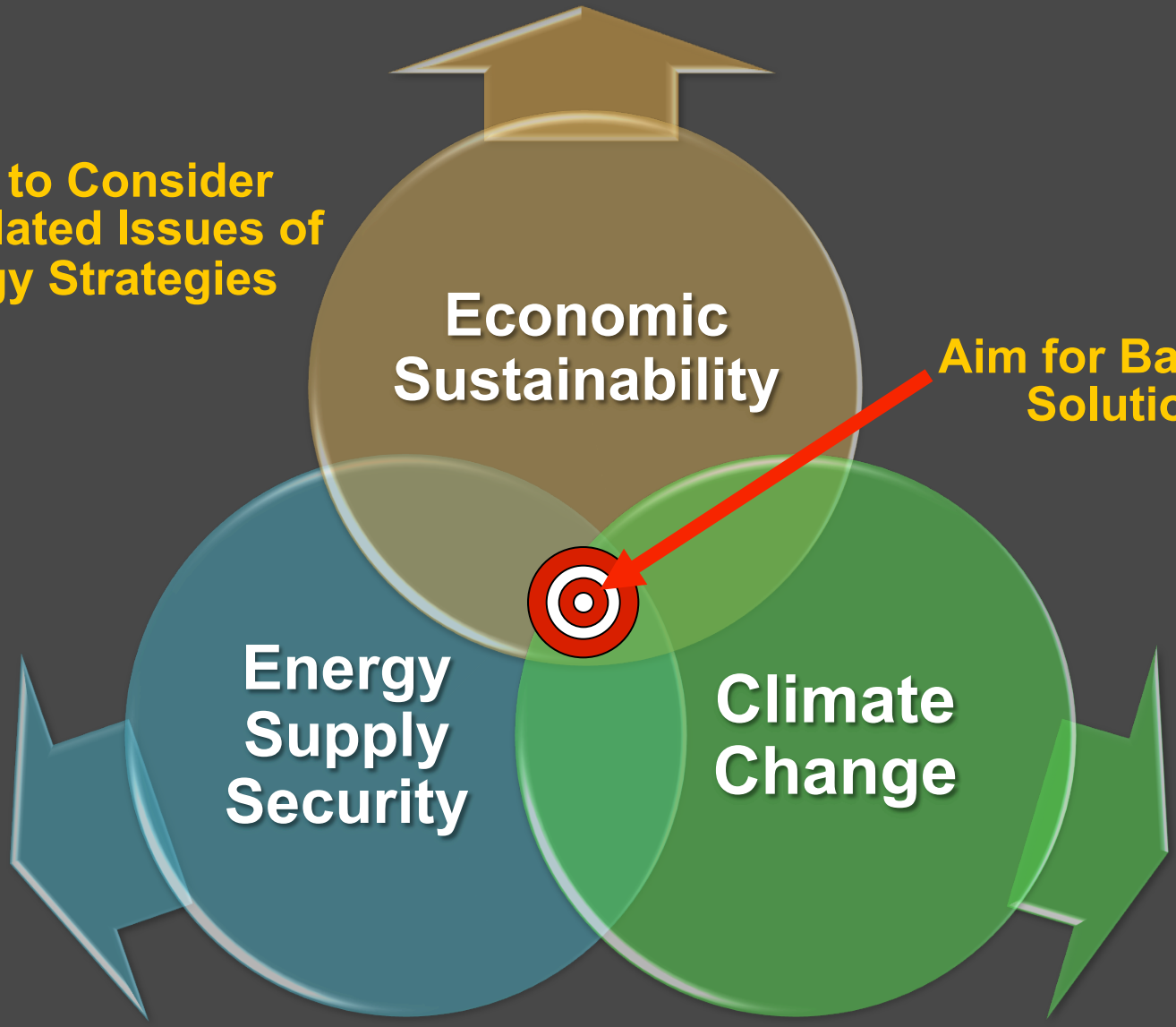


Top Ten Problems Facing Humanity Over the Next 50 Years

- Energy
- Water
- Food
- Environment
- Poverty
- Terrorism and War
- Disease
- Education
- Democracy
- Population

National Energy Strategy

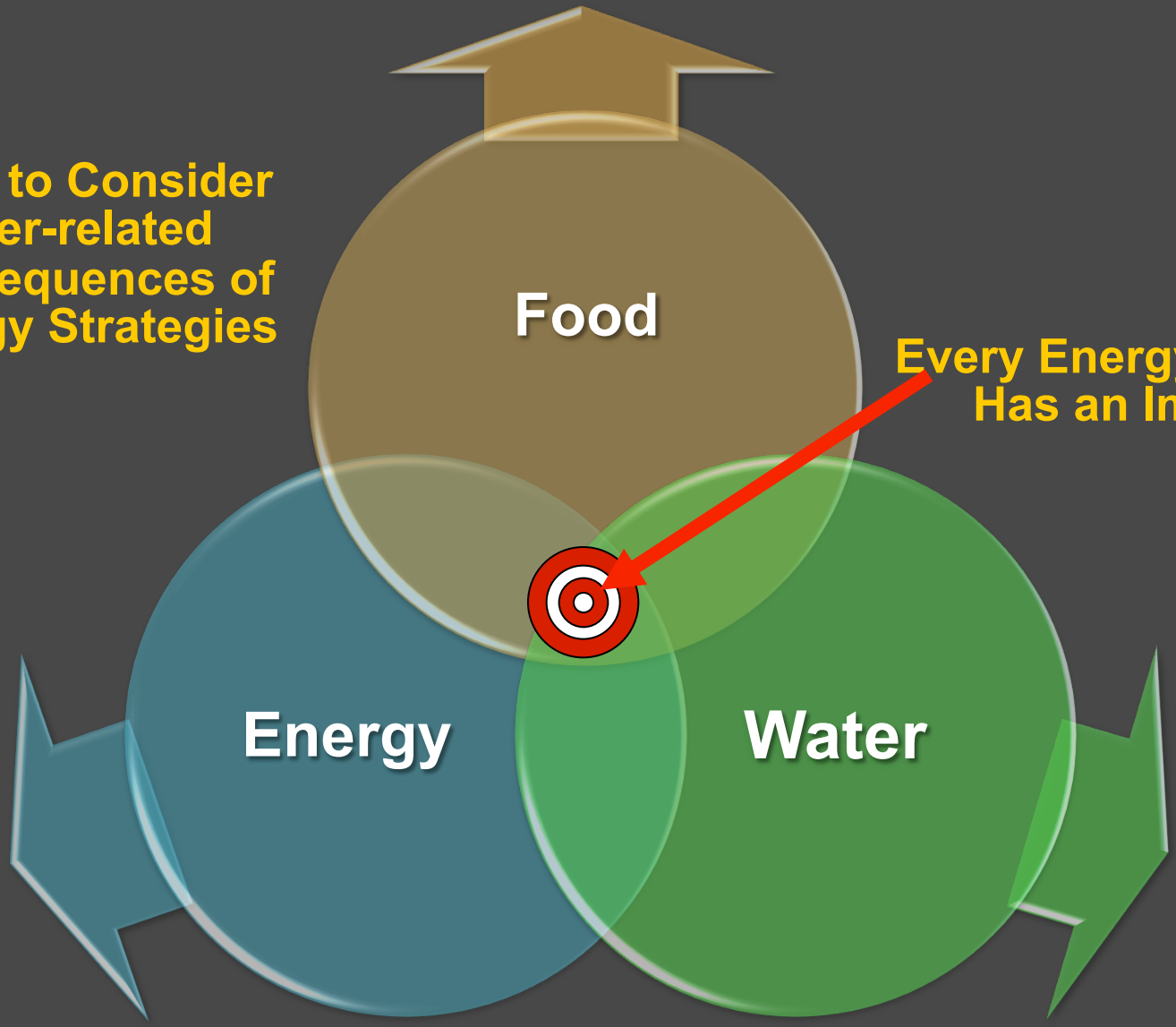
Need to Consider Inter-related Issues of Energy Strategies



Tim Skone DOE/NETL 2008

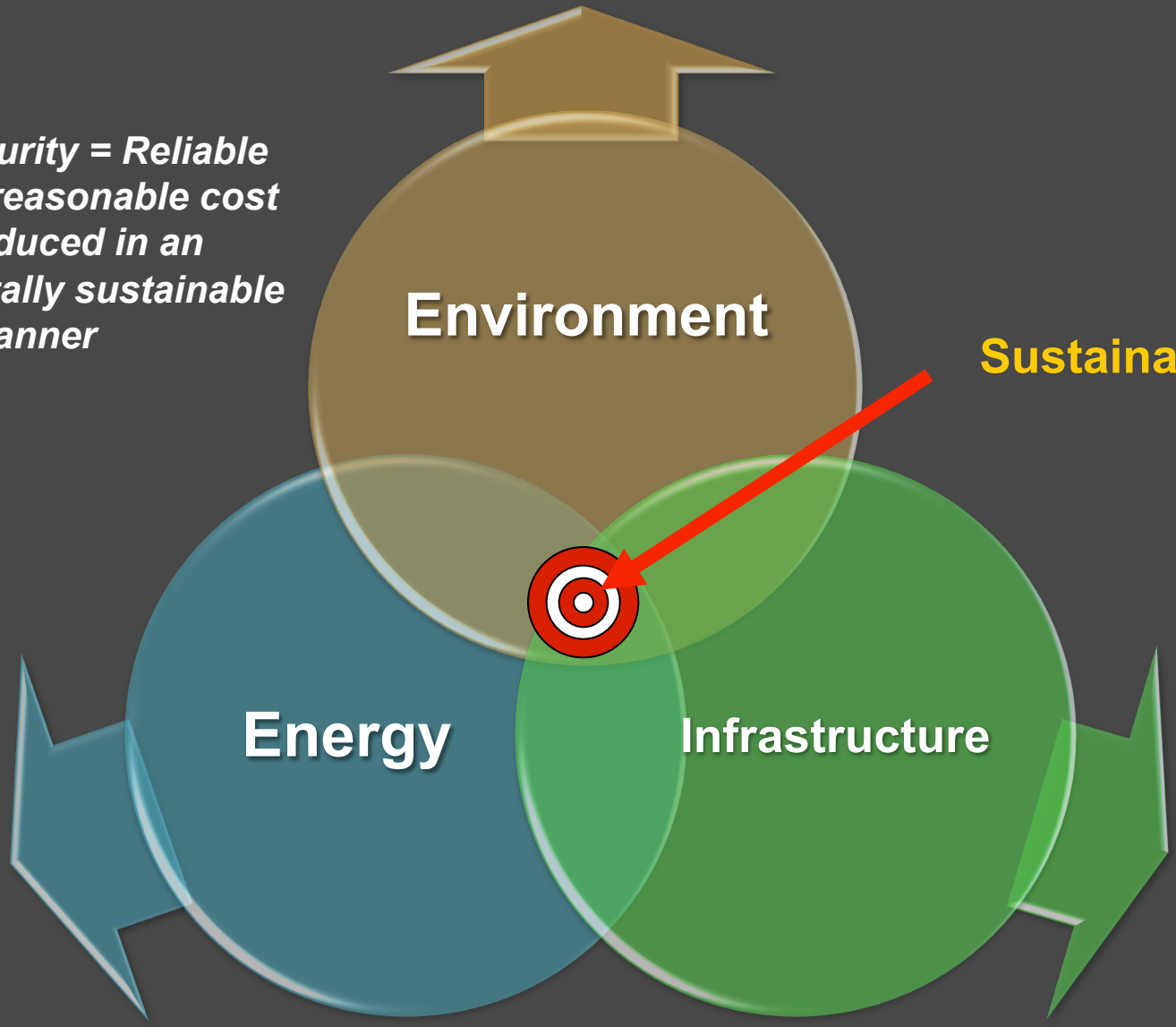
Global Energy Strategy

Need to Consider Inter-related Consequences of Energy Strategies



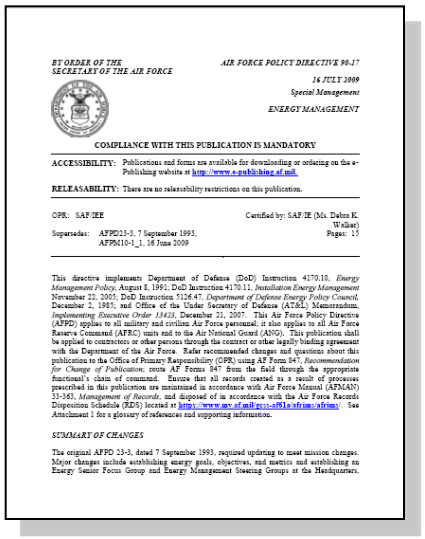
Sustainable Energy Strategy

Energy Security = Reliable supply at a reasonable cost and produced in an environmentally sustainable manner



U.S. AIR FORCE

Air Force Energy Policy



BY ORDER OF THE SECRETARY OF THE AIR FORCE

AIR FORCE POLICY DIRECTIVE 90-17

16 JULY 2009

Special Management

ENERGY MANAGEMENT

COMPLIANCE WITH THIS PUBLICATION IS MANDATORY

ACCESSIBILITY: Publications and forms are available for downloading or ordering on the e-Publishing website at http://www.e-publishing.af.mil.

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OPR: SAF/IEE

Certified by: SAF/IE (Ms. Debra K. Walker)

Supersedes: AFPD23-3, 7 September 1993, AFPM10-1_1, 16 June 2009

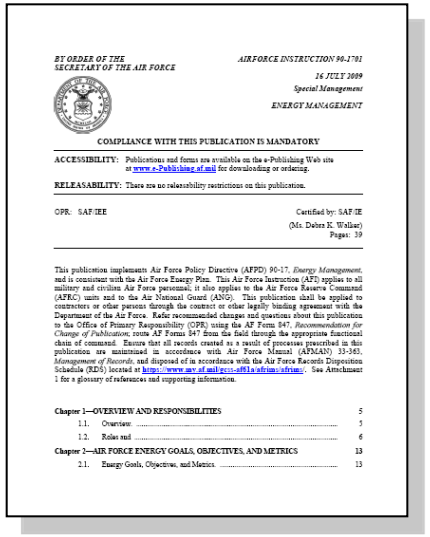
Pages: 15

This directive implements Department of Defense (DoD) Instruction 4170.10, *Energy Management Policy*, August 5, 1991; DoD Instruction 4170.11, *Installation Energy Management* November 22, 2005; DoD Instruction 5126.47, *Department of Defense Energy Policy Council*, December 2, 1985; and Office of the Under Secretary of Defense (AT&L) Memorandum, *Implementing Executive Order 13423*, December 21, 2007. This Air Force Policy Directive (AFPD) applies to all military and civilian Air Force personnel; it also applies to all Air Force Reserve Command (AFRC) units and to the Air National Guard (ANG). This publication shall be applied to contractors or other persons through the contract or other legally binding agreement with the Department of the Air Force. Refer recommended changes and questions about this publication to the Office of Primary Responsibility (OPR) using AF Forms 847, *Recommendation for Change of Publication*; route AF Forms 847 from the field through the appropriate functional's chain of command. Ensure that all records created as a result of processes prescribed in this publication are maintained in accordance with Air Force Manual (AFMAN) 33-363, *Management of Records*, and disposed of in accordance with the Air Force Records Disposition Schedule (RDS) located at https://www.my.af.mil/gcss-af61a/afrims/afrims/. See Attachment 1 for a glossary of references and supporting information.

SUMMARY OF CHANGES

The original AFPD 23-3, dated 7 September 1993, required updating to meet mission changes. Major changes include establishing energy goals, objectives, and metrics and establishing an Energy Senior Focus Group and Energy Management Steering Groups at the Headquarters,

AFPD 90-17



BY ORDER OF THE SECRETARY OF THE AIR FORCE

AIR FORCE INSTRUCTION 90-1701

16 JULY 2009

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ENERGY MANAGEMENT

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Pages: 39

This publication implements Air Force Policy Directive (AFPD) 90-17, *Energy Management*, and is consistent with the Air Force Energy Plan. This Air Force Instruction (AFI) applies to all military and civilian Air Force personnel; it also applies to the Air Force Reserve Command (AFRC) units and to the Air National Guard (ANG). This publication shall be applied to contractors or other persons through the contract or other legally binding agreement with the Department of the Air Force. Refer recommended changes and questions about this publication to the Office of Primary Responsibility (OPR) using the AF Form 847, *Recommendation for Change of Publication*; route AF Forms 847 from the field through the appropriate functional chain of command. Ensure that all records created as a result of processes prescribed in this publication are maintained in accordance with Air Force Manual (AFMAN) 33-363, *Management of Records*, and disposed of in accordance with the Air Force Records Disposition Schedule (RDS) located at https://www.my.af.mil/gcss-af61a/afrims/afrims/. See Attachment 1 for a glossary of references and supporting information.

AFI 90-1701

Formally established the AF Energy Program: Strategy, Goals, Objectives and Metrics

U.S. Air Force Energy Approach

Vision:

Make Energy A Consideration In All We Do™

Strategy:

Reduce Demand

Increase Supply

Change the Culture

Air Force 2008 Energy Use

Over $9 billion spent for energy in 2008

Aviation

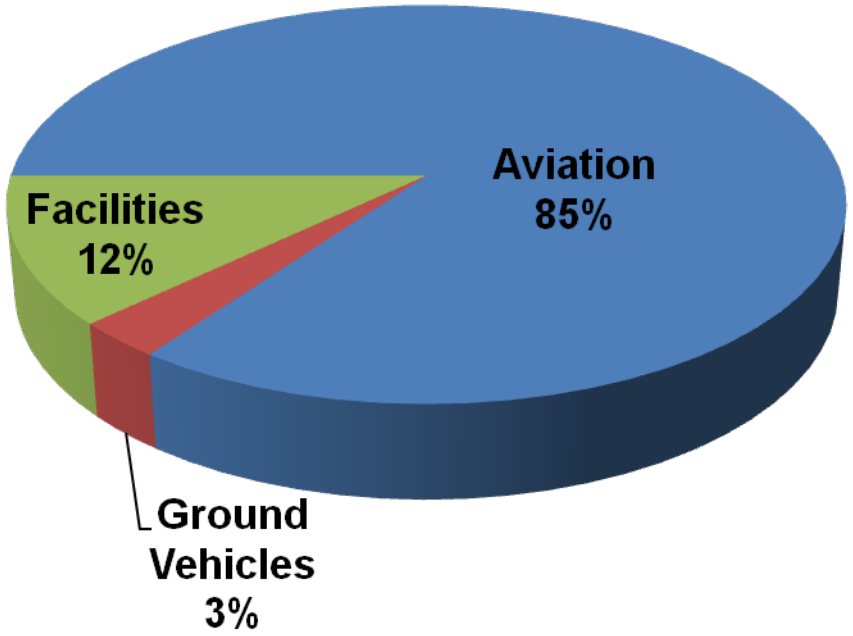
- **Fuel Used: 2.4B gallons**
- **Fuel Cost: $7.7B**

Facilities

- **Energy Used: 66.8M MBTU**
- **Energy Costs: $1.1B**

Ground Equipment and Vehicles

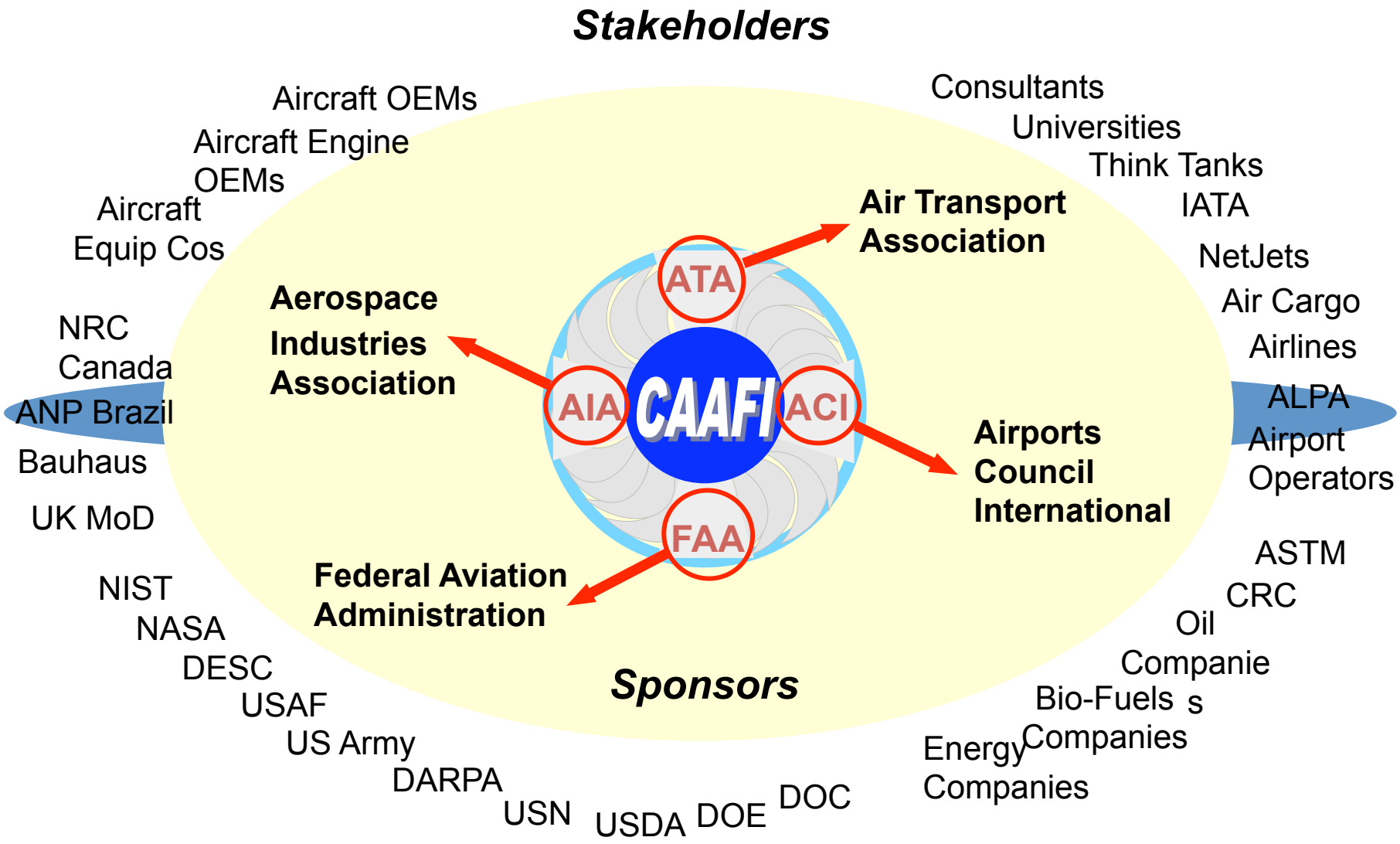
- **Fuel Used: 89.8M gallons**
- **Fuel Costs: $284.2M**



SOURCE: AF Total Cost of Operations Data Base

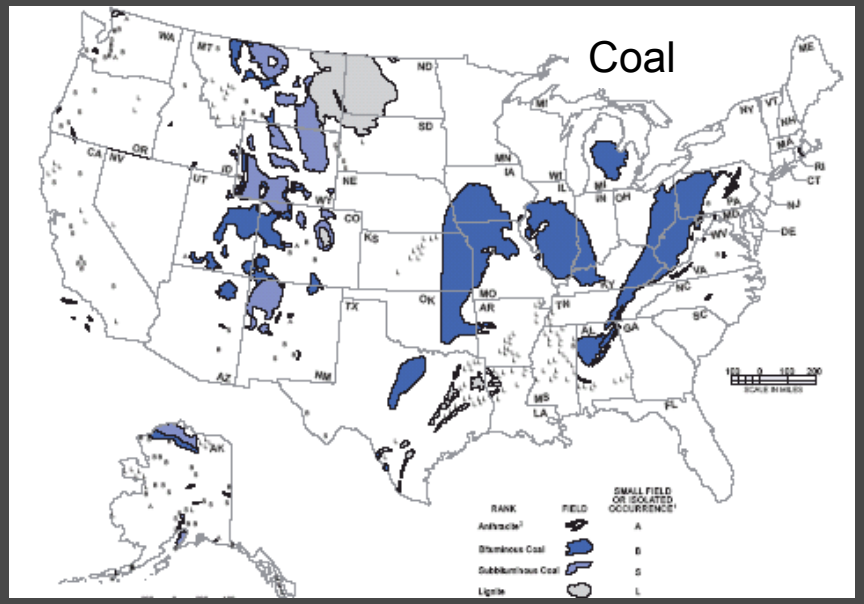
DoD Aviation ~10% of domestic jet fuel market

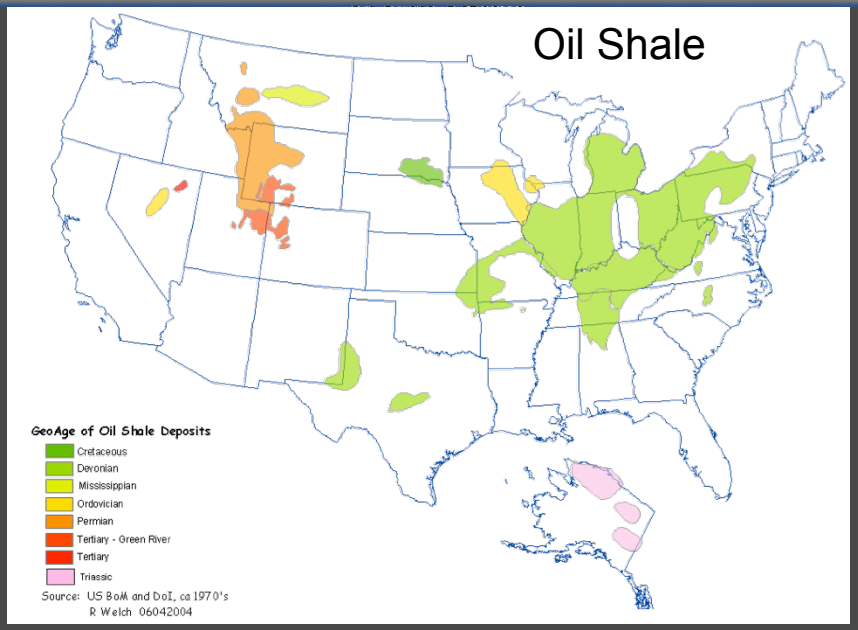
CAAFI's Sponsors / Stakeholders



….Over 300 Sponsors/ Stakeholders from All Continents

Alternatives to Oil: US Energy Resources

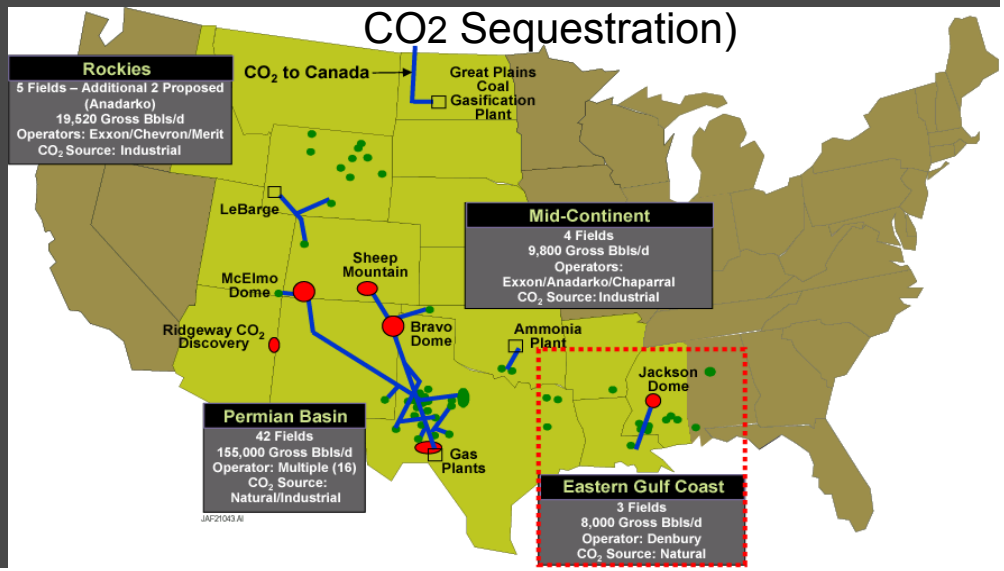




Domestic Resources

- 1.4 trillion barrels (shale)
- 900 billion barrels of FT (coal)
- 0.15 billion barrels (pet coke)
- 22.7 billion barrels oil reserves
- 240 billion barrels of oil (EOR)
- Billion+ tons of biomass

Total 2.3+ trillion barrels equivalent



RZ-08-0530

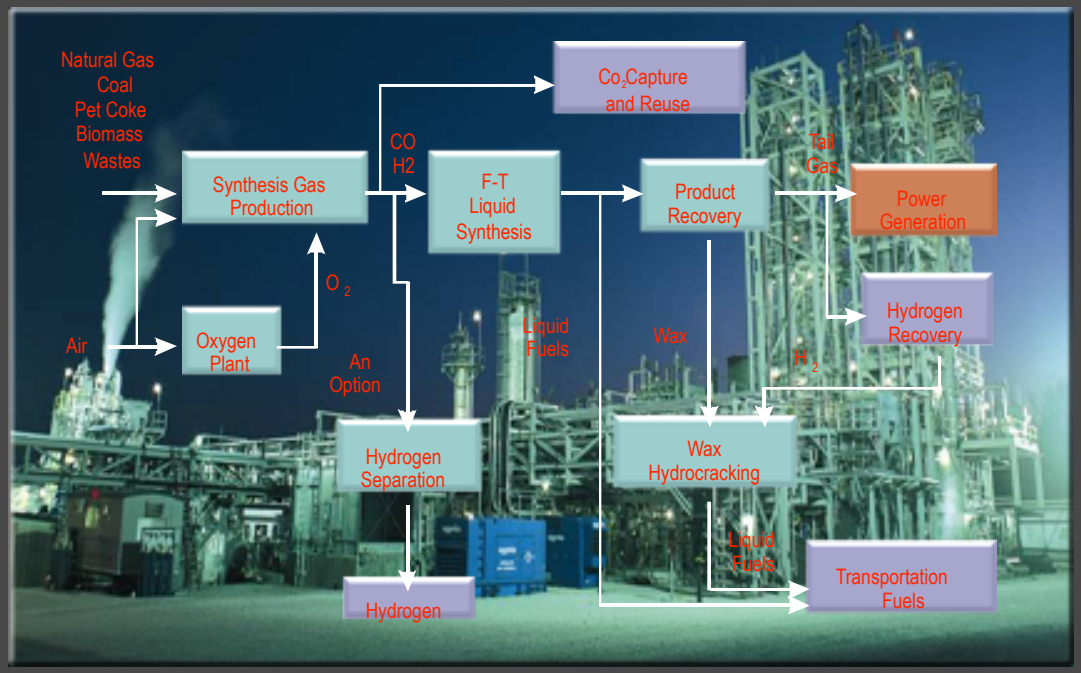
First Generation Alternative Fuels

Mature Process:

Fischer Tropsch is a proven process with benefits including:

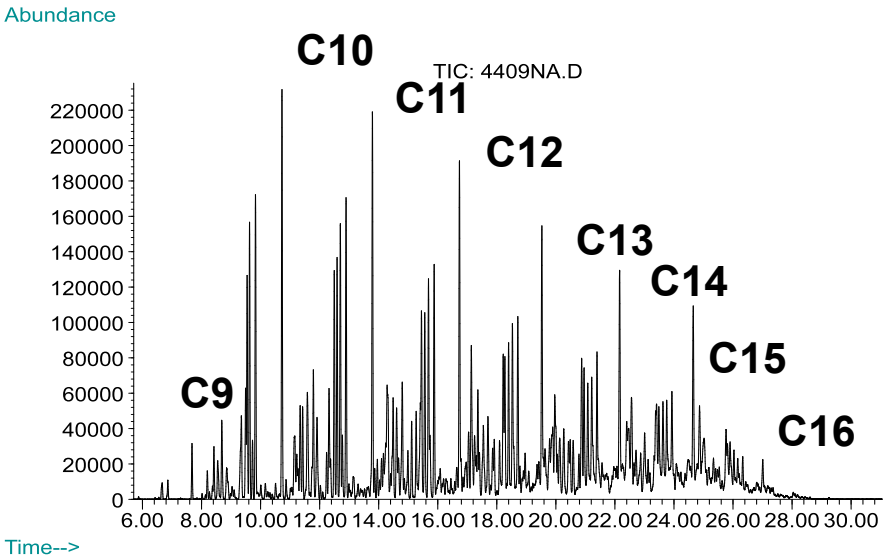
- Maturity: South African aviation use 1999
  - CTL – South Africa, China
  - GTL – Malaysia, Middle East
  - BTL -- Germany
- Chemical similarities to conventional fuels
- Manufactured fuel
  - No sulfur
  - Reduced particulates
  - High/Low temperature stability

Fischer-Tropsch Technology

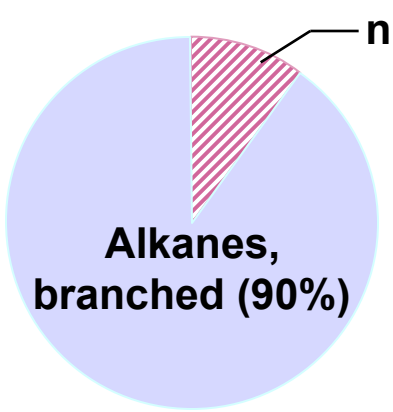


FT Fuels Reduce Emissions

- **Less Pollutant Emissions**
  - **~3.5% less CO_2 (100% FT)**
  - **50% to 90% less particulate matter (PM)**
  - **100% reduction in SOx**
  - **~1% less fuel burn (increased gravimetric energy density)**



Hydrocarbon types in Syntroleum S-5



Zero aromatics

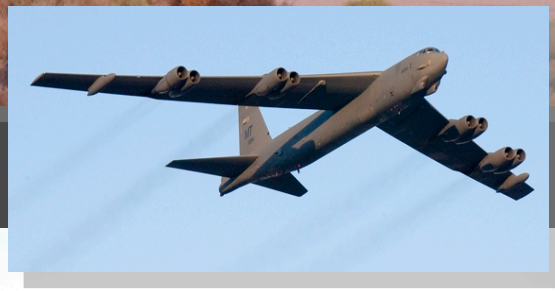
Zero sulfur

No heteroatoms

Highly Paraffinic Fuel – normal and isoparaffins
Petroleum derived fuels are rich in aromatics, cycloparaffins, and heteroatoms

B-52 Certified for 50/50 Blend!

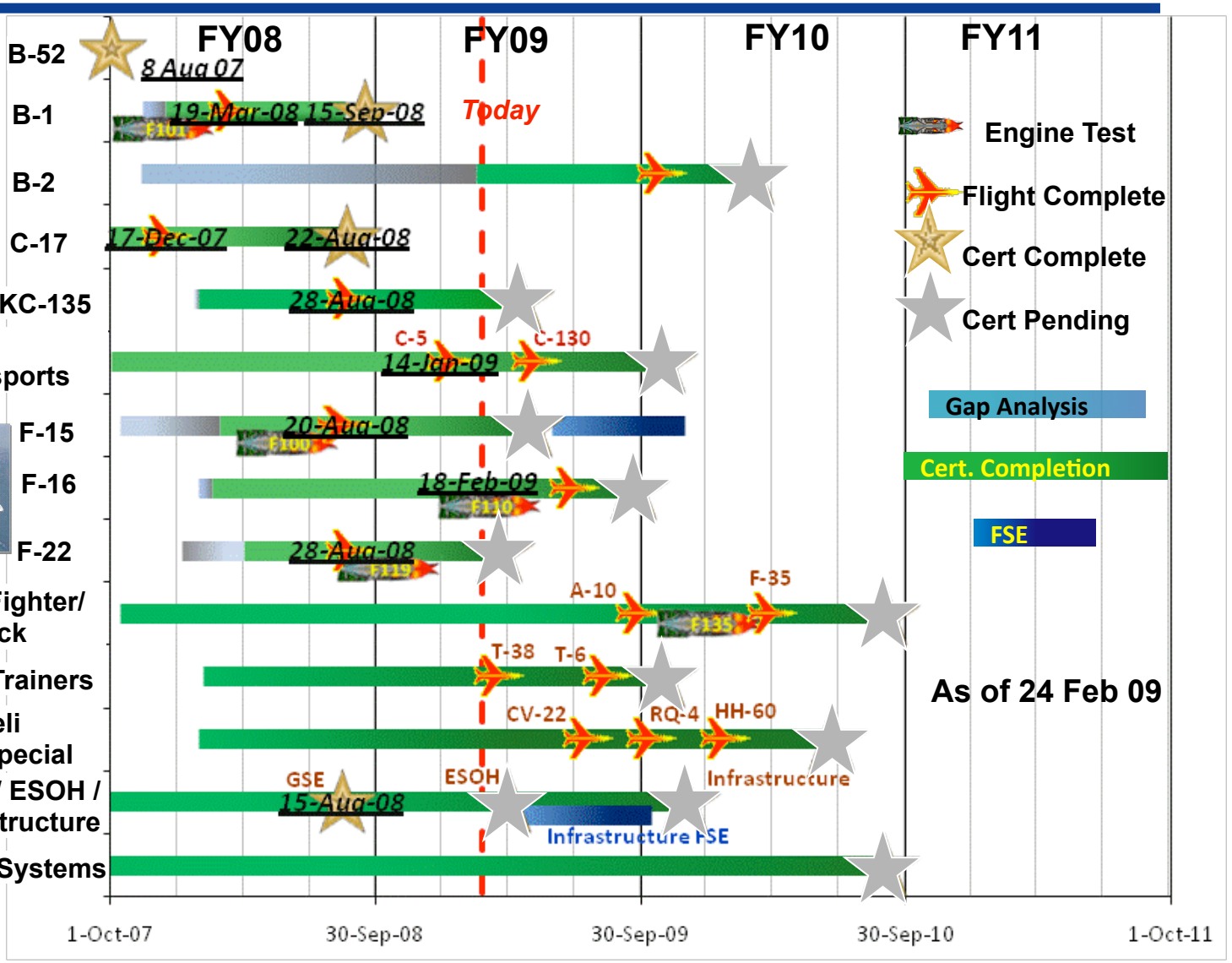
8 Aug 2007



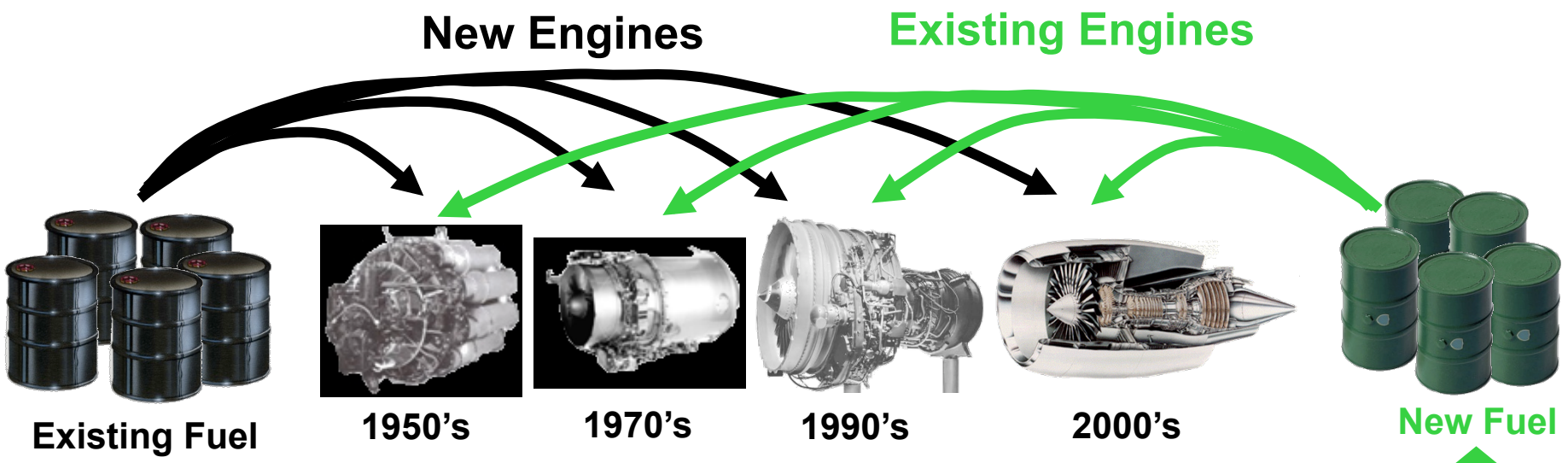
SYNTHETIC FUEL BLEND CERTIFIED
Primitus Nationus

Schedule-Synthetic Fuel Blend

U.S. AIR FORCE



The Certification Challenge



Drop-In Replacement
50/50 Blend

Mark Rumizen FAA 2008

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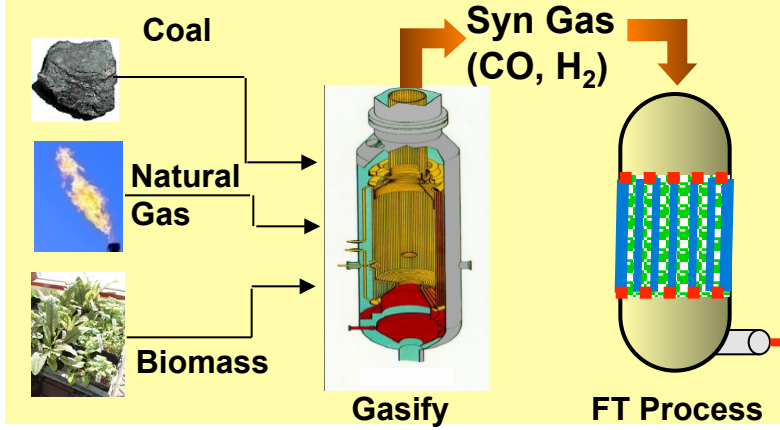
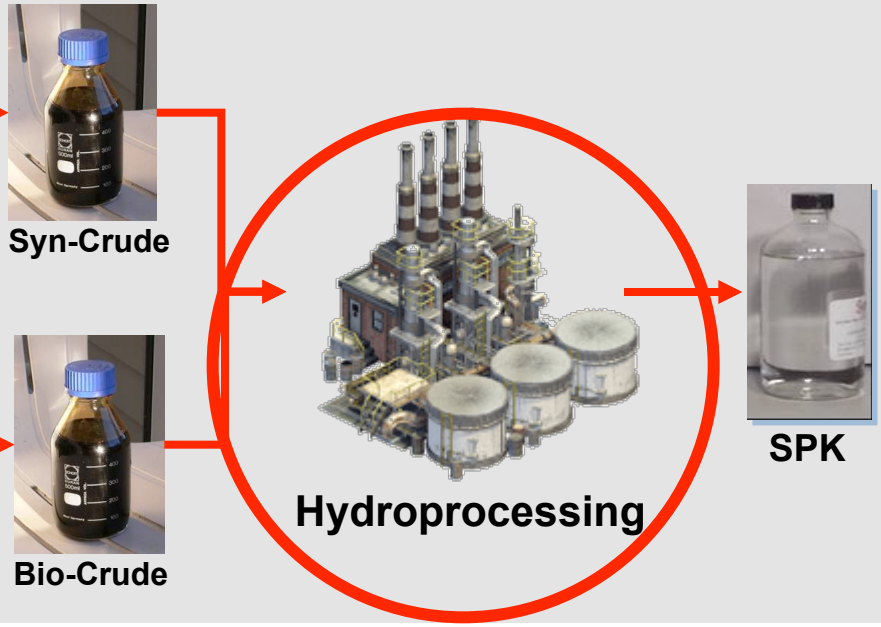
Synthetic Blend Components in Certification Phase

AF Certification complete in 2010 Fuel Class Listed in Int'l Fuel Specifications (Expected Sept '09)

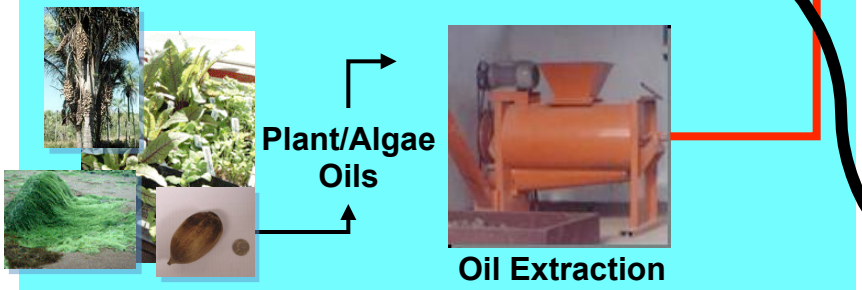
Fischer-Tropsch (FT)



Conventional Refinery Processes



Hydroprocessed Renewable Jet (HRJ) from Bio-Oils

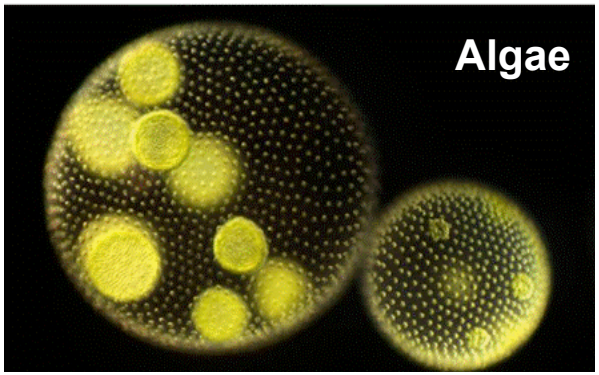


Fit-For-Purpose Property Testing Underway

Mark Rumizen FAA 2009

Hydrotreated Renewable Jet "HRJ" Fuels

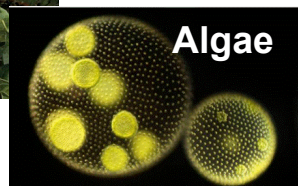
Animal Fats
(Tyson Syntroleum)

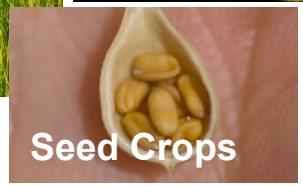


U.S. AIR FORCE

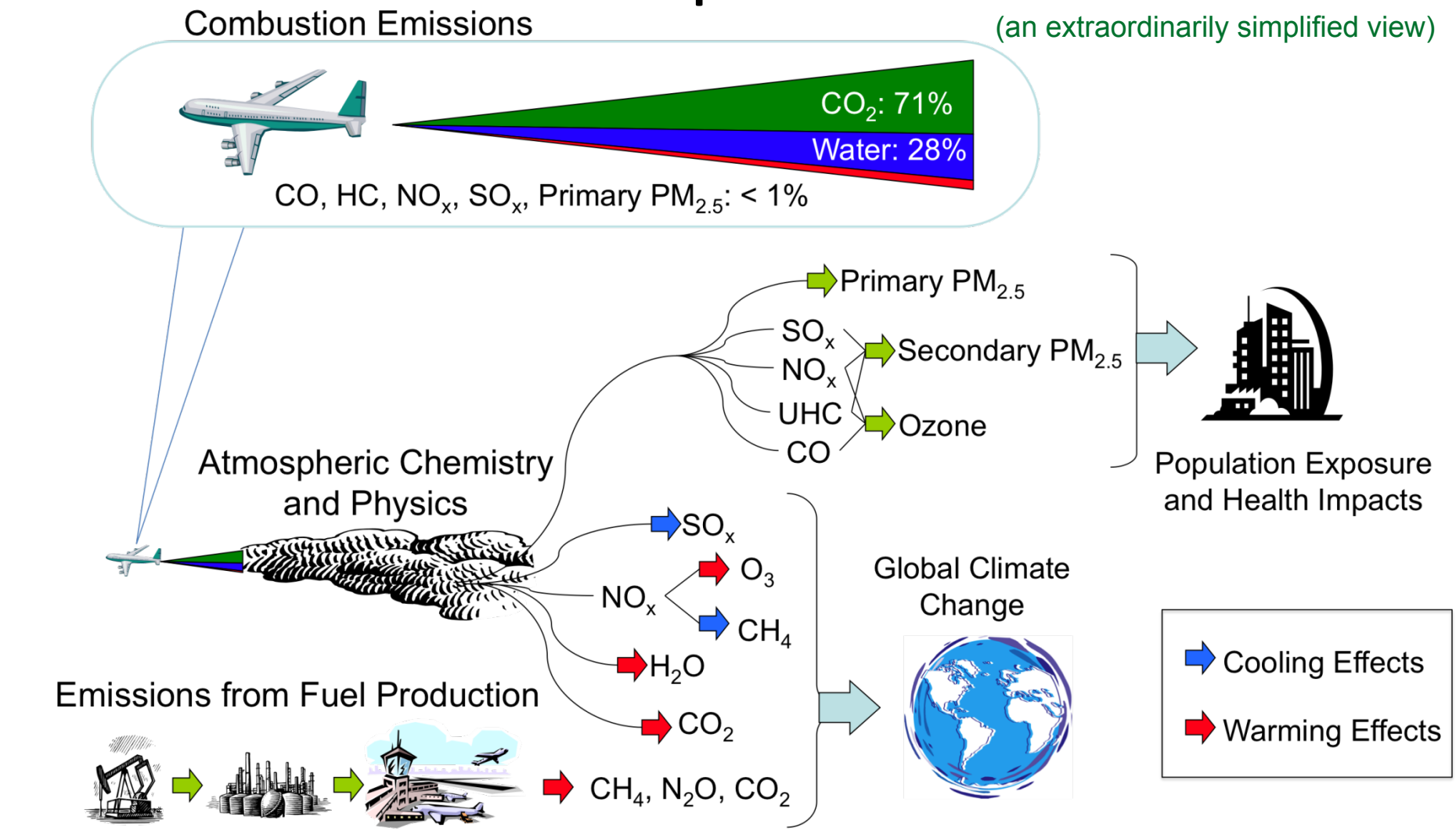
Increase Supply:
Biomass-Derived Fuel Blend Certification

- Identifying and characterizing biomass jet fuel
  - Foundation for next certification step
- "Hydrotreated Renewable Jet" (HRJ)
  - Rapid certification possible due to composition similarities to Fisher-Tropsch
  - Reduce lifecycle greenhouse gases (joint FAA/DOE/EPA studies underway)
  - Testing DARPA 100% biojet candidates
  - Evaluating Syntroleum/Tyson "yellow grease" HRJ
- Other biomass-derived fuels
  - Non-food seed oils (near term)
  - Halophytes, algae (far term)
  - Cellulosic materials (far term)



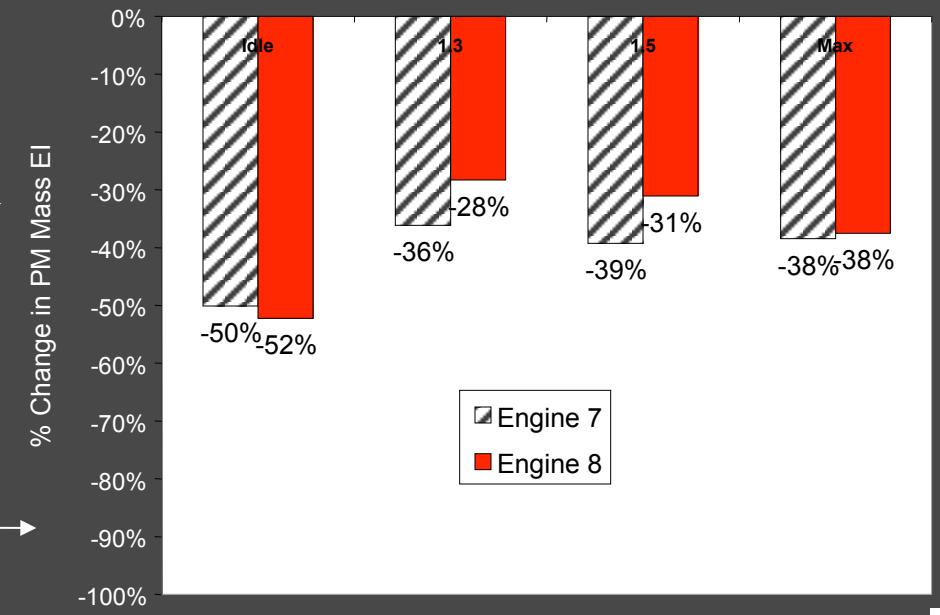


Emissions and Environmental Impacts



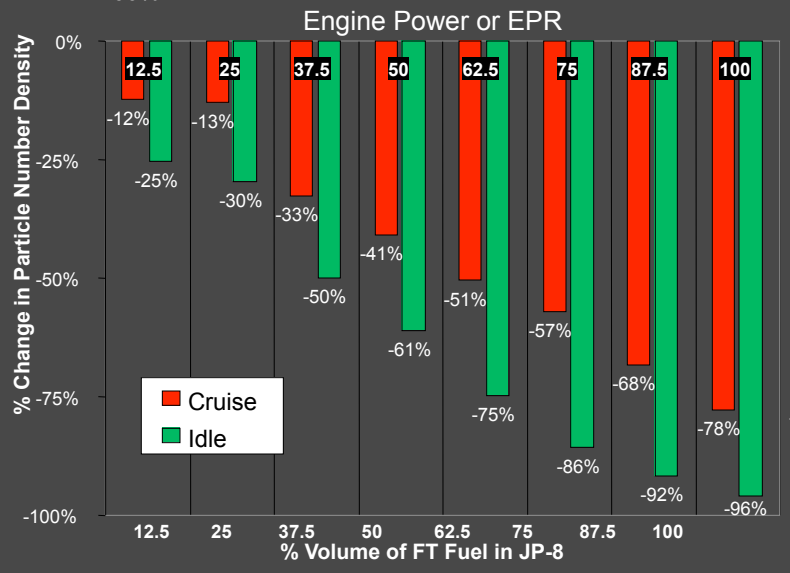
Jim Hileman MIT 2009

Fischer-Tropsch Fuels
Significantly Reduced Particulate Emissions



TF33 Engine/ B-52 Aircraft

30-50% reduction in Particulate Mass EI with 50/50 FT/ JP-8



T63 Engine

75-95% reduction in Particle Number with 100% FT

U.S. Air Force Greenhouse Gas Inventory Initiative

- Voluntary carbon dioxide (CO_2) inventory used to:
  - Evaluate policy and operational impacts
  - Support sustainability
  - Identify risk areas
  - Understand investment and mitigation areas

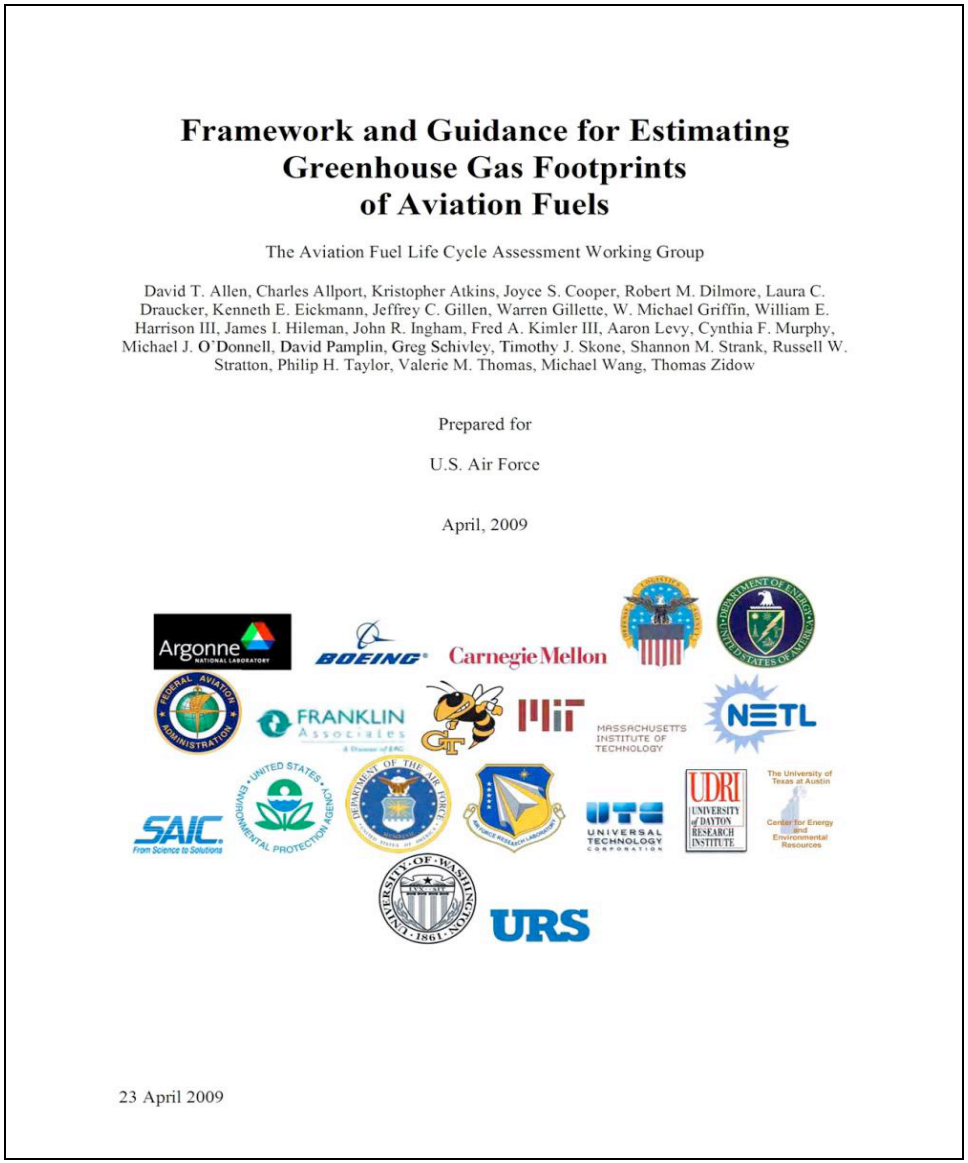
2007 CO_2 Emissions (million metric tons)	
Aviation Operations	23.98
Facility Electricity and Steam	6.93
Stationary Fuel Combustion	2.37
Ground Transportation and Equipment	1.12
TOTAL	**34.40**

CO_2 inventory paves way for change

Energy Independence and Security Act of 2007
Section 526

"No Federal Agency shall enter into a contract for procurement of an alternative or synthetic fuel, including fuel produced from nonconventional petroleum sources, for any mobility-related use, other than research and testing, unless the contract specifies that the lifecycle greenhouse gas emissions associated with the production and combustion of the fuel supplied under the contract must, on an ongoing basis, be less than or equal to such emissions from the equivalent conventional fuel produced from conventional petroleum sources."

GHG Life Cycle Analysis



Framework and Guidance for Estimating Greenhouse Gas Footprints of Aviation Fuels

The Aviation Fuel Life Cycle Assessment Working Group

David T. Allen, Charles Allport, Kristopher Atkins, Joyce S. Cooper, Robert M. Dilmore, Laura C. Draucker, Kenneth E. Eickmann, Jeffrey C. Gillen, Warren Gillette, W. Michael Griffin, William E. Harrison III, James I. Hileman, John R. Ingham, Fred A. Kimler III, Aaron Levy, Cynthia F. Murphy, Michael J. O'Donnell, David Pamplin, Greg Schivley, Timothy J. Skone, Shannon M. Strank, Russell W. Stratton, Philip H. Taylor, Valerie M. Thomas, Michael Wang, Thomas Zidow

Prepared for

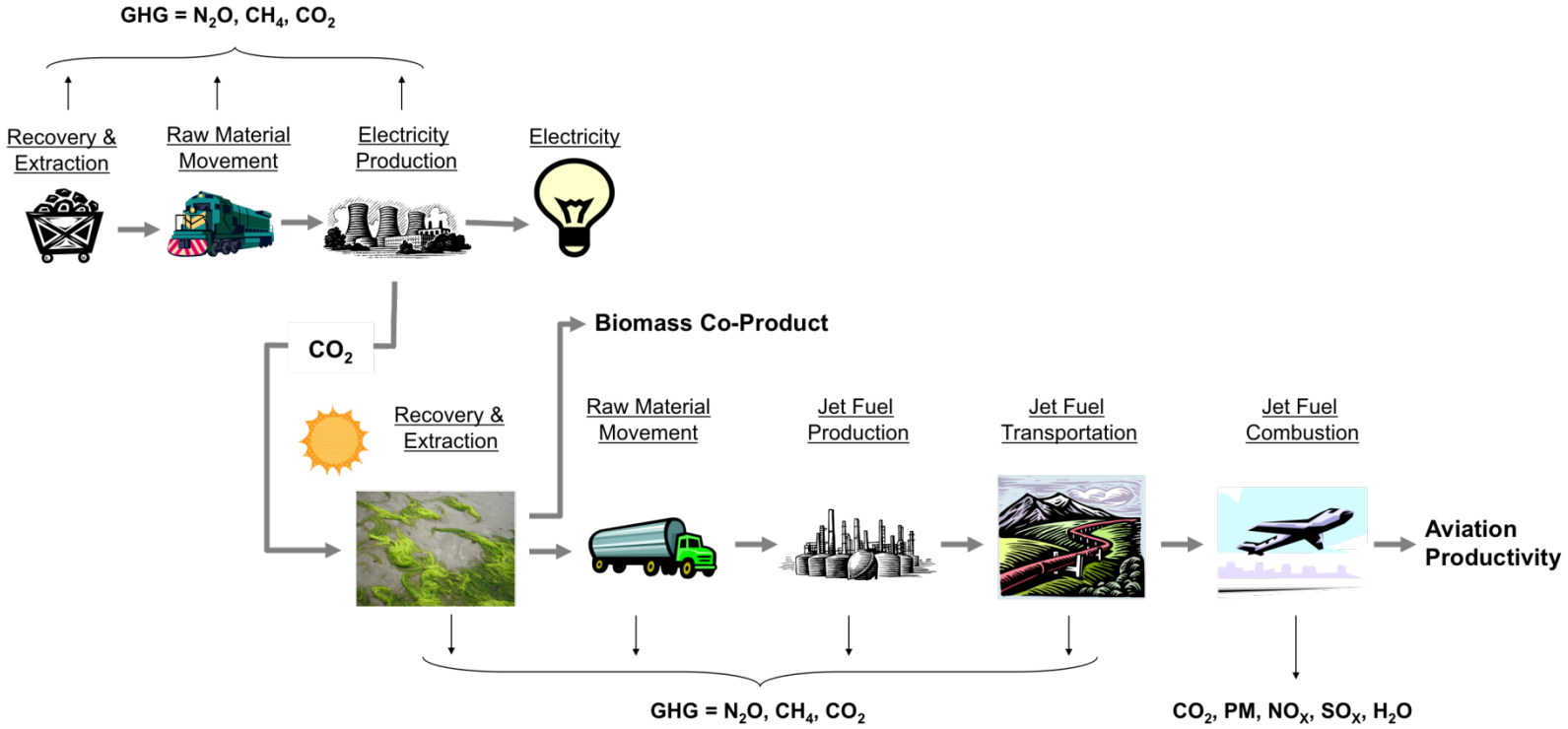
U.S. Air Force

April, 2009

23 April 2009

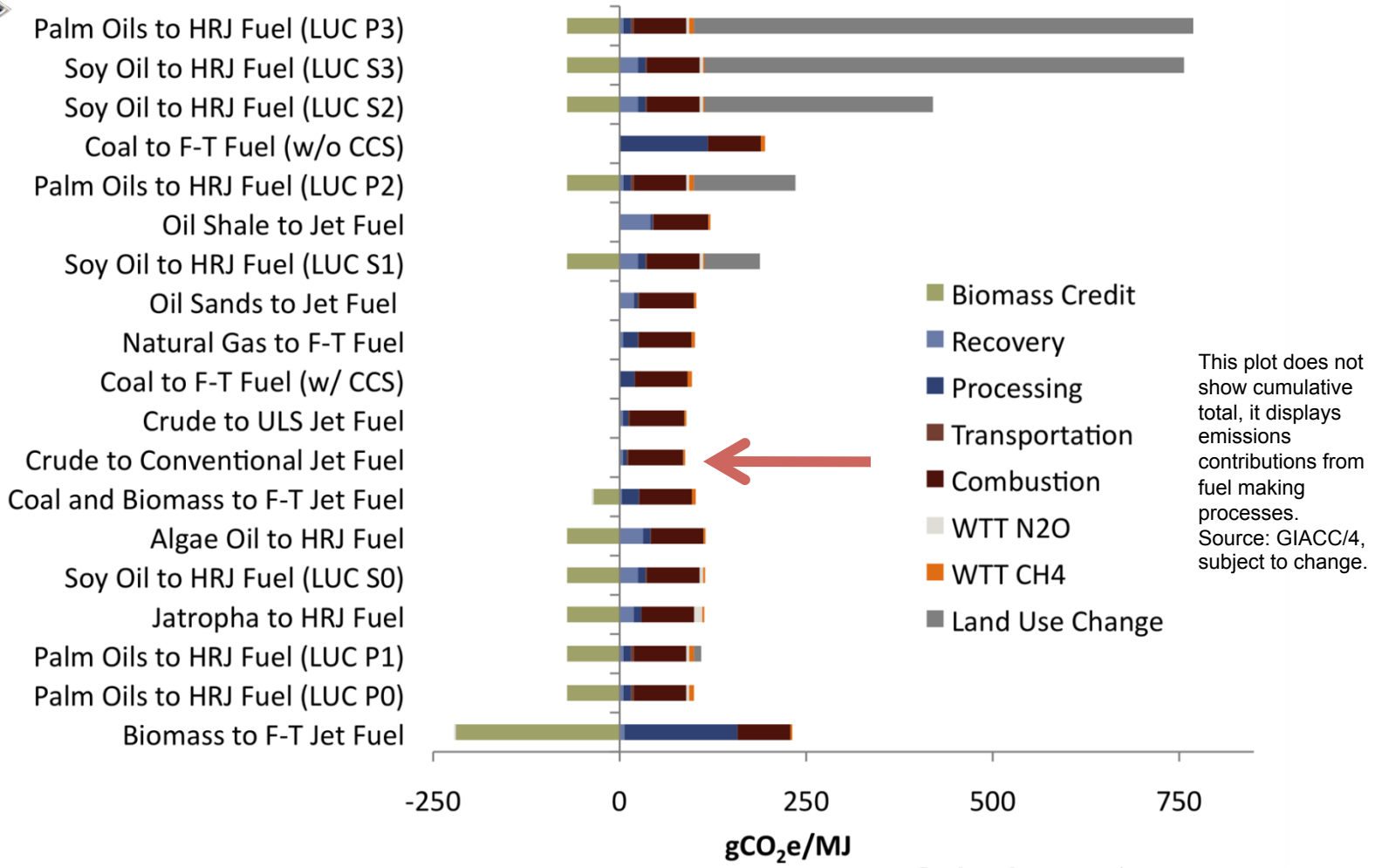
- **Guidance for GHG LCA**
  - Draft Issued April 23
  - Includes Land-Use Impacts
- **USAF Led Working Group**
  - CAAFI, DOE, Universities, FAA, Boeing
- **Peer Review Complete – revision in progress**

Well-to-Wake GHG Emissions Algal-based Jet Fuels



- To achieve commercial growth rates, algae must be “fed” carbon dioxide from another source (beyond ambient).
- Have electricity, aviation, and biomass co-product output.

Life-Cycle GHG Emissions



This plot does not show cumulative total, it displays emissions contributions from fuel making processes. Source: GIACC/4, subject to change.

Land use change and process uncertainties contribute to potential problems using some alternative fuels

Jim Hileman MIT 2009

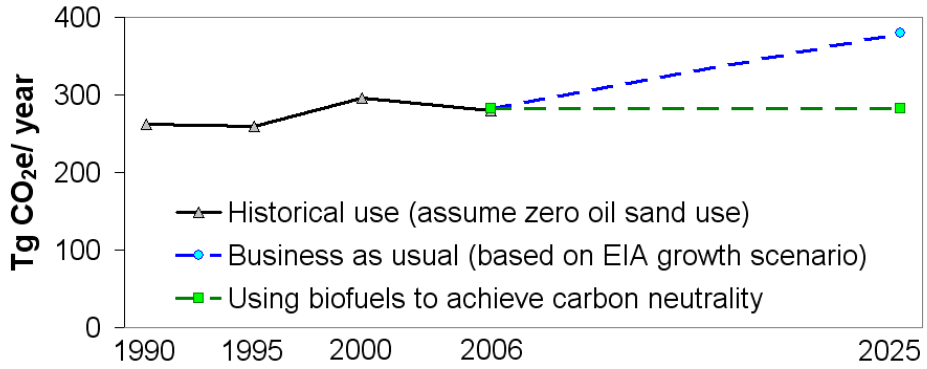
Land use change scenarios

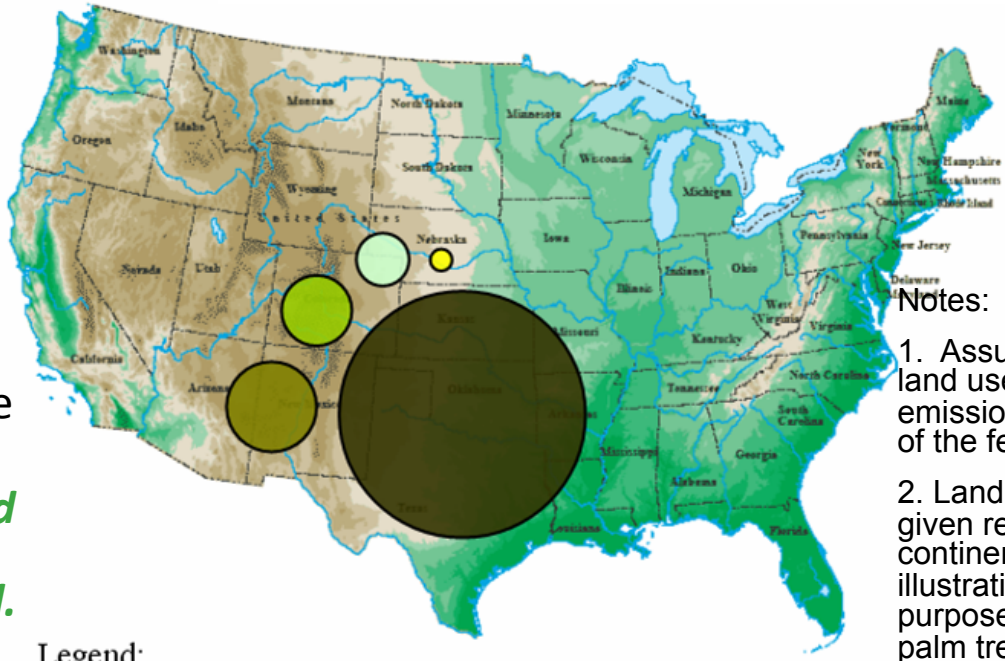
Soy oil to biojet pathway scenarios		Palm oil to biojet pathway scenarios	
LUC-S0	No land use change	LUC-P0	No land use change
LUC-S1	Grassland conversion to soybean field	LUC-P1	Logged over forest conversion to palm plantation field
LUC-S2	World wide conversion of non-cropland	LUC-P2	Tropical rainforest conversion to palm plantation field
LUC-S3	Tropical rainforest conversion to soybean field	LUC-P3	Peatland rainforest conversion to palm plantation field

Potential for Renewable Fuels - H.M. Wong S.M. Thesis (2008)[5]

Carbon Neutral U.S. Aviation Growth

- Assessed potential for carbon neutral growth from 2006 to 2025.
- Analysis used biofuel life-cycle GHG emissions and yield per hectare.
- Circles show land area requirements for three existing and two hypothetical feedstocks.
- Soybean and palm requirements both exceed current production levels.
- Analysis looked at single feedstock solutions – practical approach is to consider multiple feedstock solutions.
- ***Need feedstocks with high yield and low life-cycle emissions that do not require arable land.***





Notes:

1. Assumed no land use change emissions with all of the feedstocks.

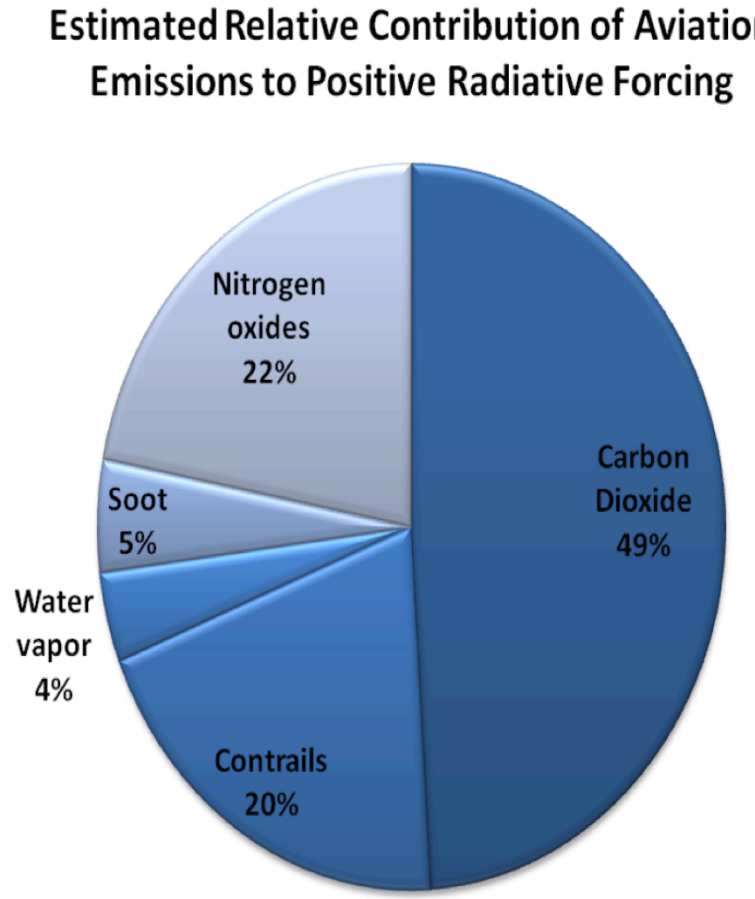
2. Land areas are given relative to continental U.S. for illustrative purposes (e.g., palm trees do not grow in Colorado).

Legend:

- Soy oil (oil yield~550L/ha)
- Herbaceous biomass (using F-T process with ~11,000 kg biomass/ha)
- Palm oil (oil yield ~5600 L/ha)
- Feedstock B (oil yield~10,000L/ha)
- Feedstock D (oil yield~50,000L/ha)

Jim Hileman MIT

Contributions of Aviation to Global Climate Change



- CO_2 Emissions ~50% of the impact
  - Engine efficiency and alt fuels
- Combustor design could address ~27%
  - Examine realistic lower limits for NOx and soot relative to CO_2
- Alternative fuels may impact ~74%
  - CO_2 recycling with properly chosen biofuels
  - Reductions in soot
  - Relationships between soot and sulfur and contrails exploration

GAO Report 09-554 Aviation and Climate Change

Cellulosic Fuels R&D
(Next Generation Biofuel)

Advanced Fermentation

Genetically Engineered Microbes

Fermentation

Jet Fuel

Sugar

Alcohol Oligimerization

Fermentation

Dehydroxylate

Olefins

Conventional Refinery Processes

Polymerization

Jet Fuel

Lignocellulose

Pyrolysis

Pyrolysis

Bio-Crude

Hydroprocessing

Mark Rumizen FAA 2009

Sustainability

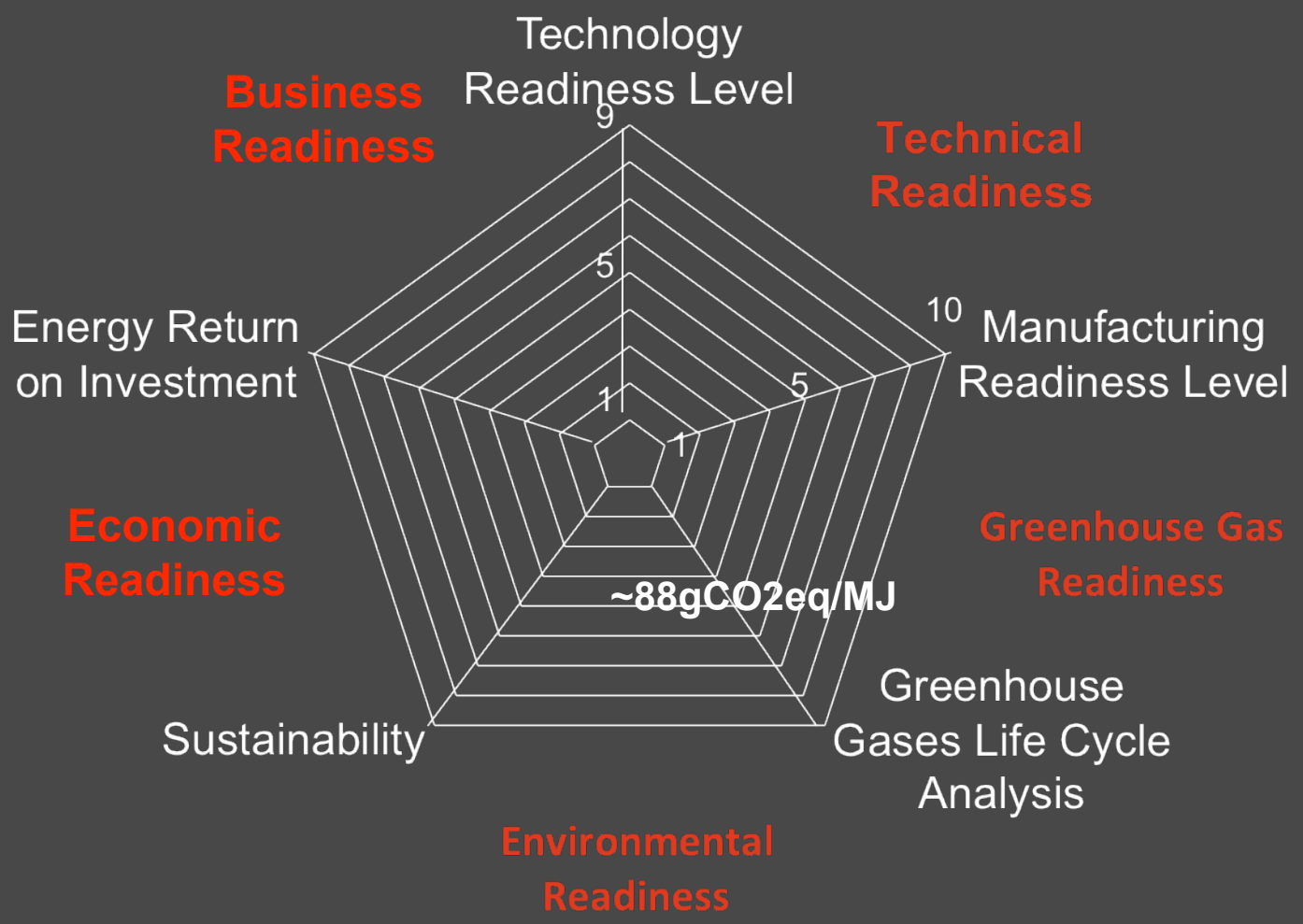
- Need to develop an aviation consensus view
  - Environmental sustainability
    - Water usage
    - Water pollution
    - Local air quality
    - Global air quality
    - Land use changes
  - Business sustainability
    - Aviation sector performance is closely linked to fuel costs

Energy Return On Investment

Notional Concept:

$$\text{Price Of Oil} \sim \frac{\text{(Energy in the Fuel) - (Energy to Produce Fuel)}}{\text{(Economic Cost of Producing bio-oil) + (Cost to Produce Fuel)}}$$

AF Alternative Fuel Score Card



RZ-08-0530

Summary

- Air Force energy policy – Reduce Demand, Increase Supply and Change the Culture
- Air Force has led the way forward to evaluate and certify alternative fuels
- Alternative fuels offer potential to reduce green house gas and particulate emissions
- Air Force will certify its entire fleet by 2011 to use a 50/50 blend of FT fuels
- Air Force starting certification of HRJ biofuels
- Cellulosic derived fuel offer potential for low carbon footprint but require R&D